

DD 21: A New Direction in Warship Acquisition

ABSTRACT

Under development during a time of new littoral missions, limited resources, rapid technology advances, and a dwindling industrial base, the Navy's 21st Century Land Attack Destroyer (DD 21) demands an unprecedented acquisition approach. This paper describes the genesis of DD 21's operational requirement and the key role of containing life-cycle costs in managing the program. It outlines the Navy's innovative procurement approach, in which key responsibilities for major design and life-cycle tradeoffs will be shifted to industry, along with an expanded role in maintenance, logistics, and training. In addition, it reviews the current status of the program.

INTRODUCTION

The Navy's 21st Century Land Attack Destroyer, or DD 21, will be the first new surface combatant built in the new century. It breaks new ground in a number of ways, not the least of which is its renewed focus on a specific mission area – land attack – following several generations of multi-purpose, blue-water surface warships oriented primarily toward anti-air warfare. The DD 21 effort comes at a time of great challenges to both the Nation and the Navy, and the management of the program has been shaped as much by these challenges as by the Navy's operational requirement. This paper will describe this unique combination of circumstances and the Navy's response to them in the planning and structure of the DD 21 program.

There are four key issues confronting today's surface Navy. First, from a force-structure standpoint, the Navy needs to address **new operational responsibilities** that derive from a growing emphasis on littoral, expeditionary warfare and the need to project power "...from the sea" to influence events on land. The bulk of the current surface combatant force was designed and built during the closing years of the Cold War, when it was planned for use in global, blue-water campaigns against a monolithic enemy bloc. Adapting these ships to support new and emerging operational requirements is likely to result in less than optimal solutions.

Next, **changing national priorities** – and the end of the Cold War – severely limit the national resources available for both sustaining naval operations and modernizing the force structure. In then-year dollars, the Navy's annual Total Obligational Authority has dropped 40 percent in the last decade, despite little change in the scope and complexity of its global responsibilities. Moreover, the most recent *Quadrennial Defense Review* (QDR) limited the surface combatant force to 116 ships, with little likelihood of future growth.

Third, with the resulting downturn in naval construction, there is increasing **difficulty in sustaining a modern industrial base** in shipbuilding, weaponry, and shipboard weapon system integration. Ensuring the viability of shipbuilders and developers of high-tech weaponry requires new programs like DD 21 to seek innovative solutions that will ultimately result in a stronger, more affordable 21st century Fleet.

Finally, **rapidly advancing military and commercially developed technologies** at the turn of this century offer vast opportunities for a whole new generation of ship types, weapons, computers, information technologies, and HM&E systems. However, assimilating these into the Navy of the future at a time of constrained resources will be challenging.

The DD 21 program has been formulated to address all four of these issues within a comprehensive systems engineering framework, and the government/industry team is well underway toward delivering the first of the class in FY 2010.

THE DD 21 REQUIREMENT

The core of the Navy's current surface combatant force structure is the more than 50 USS *Ticonderoga* (CG-47)-class Aegis cruisers and USS *Arleigh Burke* (DDG-51)-class Aegis destroyers. There are also a few dozen USS *Spruance* (DD-963)-class destroyers and USS *Oliver Hazard Perry* (FFG-7)-class frigates, most of which will be phased out by the end of the next decade. While the Aegis ships are extremely capable for anti-air warfare and are being converted for theater missile defense, they were not designed specifically for joint littoral and land-attack warfare as is DD 21. Thus, their ability to engage land targets is *currently* limited to conventional 5" 54 naval gun systems and Tomahawk Land Attack Missiles (TLAMs), used principally for strategic precision attacks. The surface Navy's Cruiser Conversion program will improve the CGs land-attack capabilities through development of the Extended Range Guided Munition (ERGM) for use with a higher-energy gun (5" 62), the Land Attack Standard Missile (LASM), and associated fire-control systems. But for the surface force to have a more decisive role in future joint expeditionary campaigns and to

support U.S. Marine Corps concepts for *Operational Maneuver From the Sea* (OMFTS), significantly more land-attack capability – in terms of weapons flexibility and payload capacity – must be introduced into surface warships. (Kuzmick and McNamara 1999, Mullen 1998)

As its name implies, the Land Attack Destroyer is intended to close that gap, particularly as the current generation of ships retire. In January 1995, the Navy began a two-and-a-half year Cost and Operational Effectiveness Analysis (COEA) to assess various platform alternatives for a 21st Century Surface Combatant (SC 21). The SC-21 COEA concluded that a *new* ship design, specifically the Maritime Fire Support Ship, was the most cost-effective alternative that could meet all requirements stated in the SC-21 Mission Need Statement (MNS). Although upgrading the Aegis fleet with new guns and missiles would help close the fire support gap, the Navy determined that the "mod DDG-51" alternative would not adequately meet the SC-21 requirement.

Shortly after completing the COEA in 1997, the SC 21 was renamed DD 21 to emphasize its "destroyer" missions. The Navy plans to acquire a class of 32 DD 21s, with two primary operational capabilities: Land Attack and Maritime Dominance.

Land Attack – The Primary Requirement

By limiting the Operational Requirements Document (ORD) to broad mission essentials, the Navy has empowered contractor teams with maximum latitude to explore a variety of design alternatives. While land attack is the ship's primary mission, DD 21 will be a multi-mission surface combatant capable of operating both independently and as an integral part of a joint or combined Expeditionary Task Force.

The land-attack requirements detailed in the ORD derive from estimates of the ship-borne firepower required to prevail in a Major Regional Conflict (MRC). There are three major subdivisions within this general mission area: Strategic Attack, Interdiction, and Fire Support. Although each of these is motivated by a separate rationale, there is significant overlap among them in terms of target sets of interest and the ranges at which they need to be engaged.

Strategic Attack comprises strikes intended to damage or destroy an enemy's strategic capacity for making war by holding enemy infrastructure targets at risk. The TLAM is effective against this class of target out to about 1,500 nautical miles (nm). The development of the Tactical Tomahawk (TACTOM) will increase this weapon's tactical capability and reduce its procurement cost.

Interdiction strikes are intended to divert, disrupt, delay, or destroy an enemy's military potential on land before it can be used effectively against friendly forces. Current requirements identify interdiction targets at ranges from 25 to 1500 nm, but except for scenarios within traditional gunnery range or where TLAM can be used against support infrastructure, today's surface combatants have no means for satisfying them (at least until the introduction of LASM).

Fire Support provides fires in tactical support of friendly ground units ashore, closely coordinated with the Ground Component Commander. The Marine Corps OMFTS concept defines a requirement for Naval Surface Fire Support (NSFS) out to 200 nm. The DD 21 program expects to meet this requirement through the development of the Advanced Gun System, which will use 155mm Extended Range Guided Munitions (ERGM) to a maximum

range of 100 nm, and the Advance Land Attack Missile (ALAM) with an expected range of between 200-300 nm. By contrast, today's surface combatants provide fire support solely by conventional, unguided munitions from 5" guns with a maximum range of 13 nm. However, a near-term modernization of Aegis cruisers (CG 52-CG-73) will increase the gun range of these ships to 63 nm while improving accuracy with the GPS (i.e., satellite)-guided ERGM.

The threats and scenarios specified in the *Surface Combatant Force Level Study* (Johns Hopkins/Applied Physics Laboratory 1995) and other ongoing force-level studies have been key to establishing the required force structure. The analysis underlying these documents enumerated the target sets allocated to ship-borne fires in representative MRCs and estimated the amount of weaponry and corresponding force levels needed to deal with them. For example, for missilery of all types, a single MRC will require an average of 3,500 vertical launch cells and present enough mobile land targets to require several thousand tactical missiles and/or "smart" gun rounds to ensure success.

Allocating these required fires among individual ships of the new class suggests the need on each for between 150 and 300 vertical launch cells and at least two guns capable of delivering 24 rounds per minute in sustained fire, with a magazine capacity for at least 1,200 rounds.

DD 21 will manage "call for fire" taskings through both shipboard and off-board mission planning and control systems, fully networked with both naval forces in company and joint forces ashore. Wide-ranging connectivity will facilitate rapid "reachback" to relevant intelligence, environmental, and geospatial data bases wherever they may be, and advanced information processing and display subsystems will provide new levels of

onboard automated fusion and interpretation.

Other Mission Area Requirements

Maritime dominance and the ability to operate both independently and as a member of a larger force are important prerequisites for land attack. As a multi-function system, DD 21 will also offer advanced capabilities in anti-air, anti-surface, and undersea warfare. The ship will be capable of establishing local area superiority against air and anti-ship missile threats within the limits of its self-defense weapons, providing area surface and undersea supremacy, and performing mine reconnaissance and avoidance. Further, DD 21 will be tactically interoperable with other battle group and joint force elements, including the ability to execute cooperative engagements.

Signature reduction and both hard- and soft-kill systems will be used to counter and disrupt the enemy's detect-to-engage sequence in the potentially hostile environments encountered in the littoral. Necessary survivability features include an advanced superstructure with integrated multi-function apertures, a shock-resistant hull, a robust electrical power distribution system, integrated magazine protection, and new levels of automation for both fighting the ship and controlling damage.

Ensuring Battle Force Interoperability for Network-Centric Warfare

DD 21 is the first new surface combatant to be designed since the Navy's decision to adopt a "network-centric" paradigm for future operations. Network-Centric Warfare (NCW) is the name of a new operational concept in which mutually shared information and a common tactical picture will permit coherent employment of the

entire naval force as a single synergistic entity. Cebrowski and Garstka (1998) have noted that NCW:

"...derives its power from the strong networking of a well-informed but geographically dispersed force. The enabling elements are a high-performance information grid, access to all appropriate information sources, weapons reach and maneuver with precision and speed of response, value-adding command-and-control (C2) processes – to include high-speed assignment of resources to need – and integrated sensor grids closely coupled in time to shooters and C2 processes."

Clearly, with a central role anticipated in joint littoral operations, DD 21 must be capable of participating in network-centric operations to the fullest. More than simply assuring communications connectivity sufficient in capacity and diversity, this implies a wide range of new capabilities to assimilate and process information onboard, derived both from own-ship sensors and multiple shared communication networks that tie together the joint force and share a common tactical picture.

DD 21 will be fully interoperable with other joint, combined, and interagency forces. It will have the command and control architecture and systems to conduct planning, situational awareness, decision-making, order generation, weapons direction, and ship system monitoring and control. An integrated external communications, internal communications, and computing environment will support real-time automated transmission, receipt, correlation, and display of all-source tactical and non-tactical information. Specifically, the ships shall be capable of exchanging information in various formats with Navy, Joint, and Combined elements to support:

- Situational Awareness – through tactical information links, voice, and video
- Targeting and Engagement – by means of real-time battle force networks and follow-on systems
- Planning and Logistics – by means of systems such as long-range, wideband communication channels and satellite broadcasting capabilities
- Land Attack and Support to Joint/Combined Forces Ashore – including the ability to interact with commanders and observers ashore for targeting and close support

DD 21 will employ a Total Ship Computing Environment (TSCE) – a fully-integrated open-system computing and information architecture that supports the execution of all tasks required by the ship's missions and supporting functional areas. This architecture will support total ship information integration using distributed and dynamic resource allocation to effectively perform all operations and permit graceful degradation for the total ship system in case of equipment and/or battle casualties. The TSCE will be a major facilitator for supporting a reduced crew size by means of a common-user interface and embedded and networked training. The TSCE will be consistent with Information Technology for the 21st Century (IT-21) initiatives and follow-on standards, and will use multi-level security features to minimize the number of independent computing environments.

THE CHALLENGE OF LIMITED RESOURCES

The QDR limits on force structure suggest that each ship of the new class must carry a payload substantial enough to dominate a

significant portion of the littoral battlespace with its own resources. DD 21's multi-warfare requirements – and especially the need for large volumes of fire in the land attack role – suggest that DD 21 will likely result in a ship approaching or even exceeding 12,000 tons. While this size may appear to belie the ship's designation as "destroyer" and militate against achieving unit and life cycle cost goals, there could be significant advantages in building a larger hull. Instead of over-constraining the design problem by attempting to package the DD 21 requirement into an arbitrarily small and densely packed hull, accepting more volume and displacement may in fact lead to a more affordable ship as a result of lower design and maintenance costs. Significantly more ordnance-carrying capacity and flight deck area are among other key operational advantages of a bigger ship.

This "big ship/small-ship" decision is a key area where intelligent tradeoffs can offer major design advantages by both increasing flexibility and adaptability while reducing total Life-Cycle Cost (LCC). The intent is to exceed DDG-51 capability in maritime dominance, land attack, survivability, and joint force connectivity, while limiting Operating and Support (O&S) costs to only 30% of those for DDG-51, or a class average of approximately \$2,700 per hour underway. The DD 21 in series per unit production cost has been targeted at \$750 million (in FY 1996 dollars) for the fifth (9th and 10th) ships from each shipyard.

The Imperative of Optimal Manning

Historically, 40-60 percent of the LCC of a surface warship has been expended on the sustenance and training of the crew. For this reason, reducing DD 21's O&S costs to 30% of DDG-51's means reducing DD 21's manning commensurately. (Bush, et al. 1998) The program's goal is to man the ship with only 95 crewmembers, down from

approximately 320 on DDG-51s. This initiative has been adopted formally as a Key Performance Parameter (KPP) for the program and has motivated a “zero-based” crewing approach, which begins with a top-down functional/task analysis aimed at defining and justifying each billet. Faced with a similar challenge onboard existing Aegis cruisers already in the Fleet, the SMARTSHIP program succeeded in reducing the USS *Yorktown*’s (CG-48) billet structure by 13%, a far cry from the 70% crew reduction required for DD 21. This much more aggressive decrease will demand an unprecedented level of innovation and automation in meeting the ship’s normal operational, logistical, combat, and damage-control functions.

State-of-the-art Human Systems Integration (HSI) techniques will be incorporated to use each crewmember more efficiently as a decision-maker, rather than a data processor. This human-factors approach is intended to encourage the re-engineering of shipboard operations and maintenance – through new materials, procedures, and innovative design initiatives – which will help enable Sailors do more warfighting and less “rust-busting.”

This revolutionary approach to shipboard manning will have far-reaching effects throughout the Navy and demand significant cultural changes. Training and skills development are a typical example. In the conventional pyramidal hierarchy of skills found aboard a surface ship, a broad base of relatively unskilled Sailors are available to do the many unsophisticated, manpower-intensive tasks now required for operating today’s warships. Since DD 21 will not have the luxury of a large pool of unskilled labor, many of the mundane shipboard tasks (e.g., painting, cooking, or cleaning) traditionally performed by seamen will need to be eliminated or automated.

The movement toward optimized manning, spearheaded by DD 21, has led Navy leadership to study new strategies and to undertake Fleet-wide initiatives for operating its warships and training its warfighters. In the case of new ships like DD 21, it also implies new design strategies as previously mentioned, as well as a new paradigm for how DD 21 billets will be filled and what qualifications will be required to fill them.

At a minimum, all crewmembers will need to be fully prepared to perform their assigned duties upon reporting onboard. With little opportunity for apprentice (i.e., on-the-job) training, these skills must be gained elsewhere, and innovative detailing will be necessary. For this same reason, DD 21 will have to be 100 percent manned. With each and every shipboard function intricately partitioned among only 95 personnel, there will no luxury to gap billets as is commonly practiced today.

Moreover, many of today’s type commander prerogatives will be affected. Current regulations for manning the bridge, combat and propulsion control spaces, and damage control infrastructure will have to be revised in light of dramatically fewer crewmembers and the growing role of shipboard automation. The requirement for DD 21 to deploy an onboard helicopter capability, with the associated personnel counted as part of the 95-member crew, also poses a unique design challenge. Today, a typical surface-ship SH-60 helicopter detachment includes 22 personnel – nearly a quarter of the DD 21 total. Clearly, significant Navy-wide innovation will be needed – in aircraft type, procedures, and mission requirements – to support a viable air capability within the 95-manpower goal.

Innovative Acquisition Strategy

The DD 21 program’s use of Other Transaction Authority (for prototypes) –

enabled by Section 845/804 of the FY 1994/97 National Defense Acts – offers the Navy more flexible and innovative procurement processes. With this authority, the DD 21 program has been able to provide minimal government direction and specification in order to afford industry design teams maximum flexibility in developing the most innovative, cost-effective proposals possible. Unique benefits of 845/804 acquisition include:

- Streamlining acquisition procedures and enables a more efficient source-selection process
- Focusing industry's independent R&D during the ship's early concept development
- Allowing use of generally accepted accounting procedures
- Facilitating non-traditional strategic industry partnerships

Industry design teams have been encouraged to start with "a clean sheet of paper" in formulating ship/system alternatives, optimized for minimal life-cycle cost, that still satisfy the ship's operational requirements. Thus, a wide range of choices is available for hull form, propulsion, combat system elements, a maintenance and sparing approach, logistics, manning, and training. Moreover, the use of prescribed Government Furnished Equipment (GFE) and Government Specific Equipment (GSE) is not encouraged or desired, leaving shipbuilders and system integrators the widest possible latitude for optimizing life cycle decisions for selecting shipboard systems. Further, the contractors will be given the opportunity to negotiate directly with sub-system suppliers to trade off cost, quantity, and delivery terms.

Full Service Contracting

A key system engineering strategy for reducing LCC is the adoption of Full Service Contracting (FSC) as a means of

enlarging the trade space accessible to designers and builders of the DD 21 "System." By giving the system designer sufficient latitude to invoke all phases of the ship's life cycle in engineering, maintenance, and personnel decisions, a broader scope for overall optimization is made available, with more opportunities to achieve lower LCC.

One approach for reaching these objectives is introducing significantly more commercialization into functions that hitherto have been done by the government – or contractors closely supervised by the government. In granting a chosen FSC more authority to make fundamental life cycle decisions and then to hold him accountable for achieving overall performance and economy, the full power of market forces can be brought to bear. The broad categories within which FSC may be exercised include:

- Engineering and Design
- Production/Construction
- Test and Evaluation
- Operator/Equipment Training
- Certification
- Maintenance and Logistics
- Modernization and Upgrade
- Disposal

In meeting these broad responsibilities, the FSC will need to monitor, analyze, and support the readiness of each ship of the class. For example, no matter where each DD 21 is forward deployed, it will require on-line access to training, maintenance, administration, and logistics support. Replacement parts will need to be automatically requisitioned over satellite links and shipped directly from suppliers to the ships. Similarly, satellite "reach-back" will provide access to subject-matter experts ashore to complement the skills of the crew and make more efficient the whole process of maintenance and repair. Similar support

will be provided for training and qualification at sea.

This new approach introduces its own array of challenges, which are addressed early on in the establishment of requirements and later prioritized in the ship's design, development, construction, test, and evaluation; and finally throughout the life cycle in how training, maintenance, supply, upgrades, and disposal are accomplished. Included in this review are current business practices, funding, operating procedures, and organizational responsibilities.

Many aspects of FSC support will require a business case analysis of current Navy infrastructure in comparison to private sector capabilities. Obviously, much of this infrastructure will need to remain in place to serve other elements of the Fleet *not* included under the FSC umbrella.

However, the success of the FSC concept will likely influence the extent to which it can be applied to other ship classes presently serviced by existing infrastructure.

AN UNPRECEDENTED DESIGN COMPETITION

As noted above, U.S. industry has taken on a much greater responsibility in making DD 21 life-cycle design tradeoffs and proposing innovative solutions. In part, this decision acknowledges the substantial lead that industry maintains over government in developing new technologies and applying them as innovations in information handling, manufacturing, transportation, and public works. During the defense contraction that followed the Cold War, research and development investment and expertise have shifted increasingly toward the private sector, forcing many defense programs, including DD 21, to seek additional resources there.

Still, the current low rate of new warship construction in the United States creates difficult problems in sustaining an adequate industrial base for the future. Not only are shipyards hard-pressed to maintain viability, but systems integrators and the whole network of second-tier and component suppliers struggle to survive. The incentive for expending private resources on research and development for warship production and for maintaining surge capacity for emergencies has all but evaporated. As the only large U.S. surface warship construction program at the beginning of the new century, DD 21 needs to play a positive role in assuring the long term stability of the industrial infrastructure, or at least not contributing to its further deterioration. These considerations have motivated the unique contracting arrangements by which the DD 21 will be designed and built.

Since the beginning of the Aegis cruiser program in the late 1970s, only two U.S. shipbuilders – Ingalls Shipbuilding, Incorporated, and Bath Iron Works – have produced surface combatants, and the construction of both Aegis cruisers and destroyers has been purposefully allocated between the two yards. Construction of the new class will also be shared between the two shipyards, if only for industrial base reasons. In this approach, the winning team would become the FSC with primary responsibility for designing the ship and its associated systems and managing the entire life cycle engineering and support of the class. Meanwhile, the remaining shipyard would still share in the construction.

Another challenge has been to maintain a reasonable degree of competition as another mechanism for controlling costs and stimulating innovation. When it became apparent in the original solicitation for the program that there might only be one responsive bidder, the Navy – with congressional approval – stepped in to restructure the competition. In negotiations

among key industry players, a "Shipbuilder's Alliance" was formed between Bath and Ingalls that proposed terms for a meaningful design competition between the two shipyards and the principal system integrators, Lockheed Martin and Raytheon Systems Corporation. The Alliance is also currently managing the competition from the industry side until the downselect anticipated in 2001.

The two teams consist of the Gold Team, led by Ingalls Shipbuilding and Raytheon, and the Blue Team, led by Bath Iron Works and Lockheed Martin. Assigned to each team is a host of other companies, as well as contracted government laboratories, specializing in different technical areas.

Regardless of who is selected, there will be significant participation from a wide spectrum of the U.S. defense industry, including companies that do not traditionally bid on defense contracts. Consequently, a strong and competitive industrial base will be maintained even in the face of limited new construction.

THE CHALLENGE OF NEW TECHNOLOGIES

The DD 21 effort coincides with rapid advances in military and commercial technologies, which present significant challenges in achieving a balance between incorporating as many emerging capabilities as possible and still containing cost, schedule, and technical risk. Two strategies for facilitating real innovation are the unprecedented latitude granted to the design teams in forging a total life-cycle systems concept as the Full Service Contractor; and the development of advanced associated technology programs managed by the Navy and shared with all offerors. For example, the Program Executive Office for Surface Strike (PEO (S)), formerly PEO for DD 21,

oversees the Multifunction and Volume Search Radars (MFR/VSR), the Advanced Gun System (AGS), the Naval Surface Fire Support (NSFS), the Advanced Land Attack Missile (ALAM), the Integrated Power System (IPS), and the Affordability Through Commonality (ATC) programs, among others.

Multi-Function Radar

MFR will be an X-band phased-array radar designed to incorporate both horizon search and fire-control capabilities into a single system. It will detect the most advanced low-observable cruise missile and aircraft threats and provide fire-control illumination for both the Evolved Sea Sparrow Missile and new variants of the Standard Missile. Based on a recent industry competition, the MFR will be designed and built by Raytheon Systems Corporation. It will use a solid-state active array whose own radar cross section will be carefully engineered to preserve stealth or signature properties of DD 21. This will require new "topside technologies" that incorporate embedded phased arrays into a composite superstructure.

Volume Search Radar

The three-dimensional VSR will be a solid state, active phased array. Complementing MFR for ship situational awareness, the VSR will be used to cue quality track data to the MFR, as well as control and monitor aircraft at long ranges. Other capabilities such as interrogating friend or foe (IFF) and detecting and locating enemy batteries ashore are under consideration.

Advanced Gun System

Managed as part of the Navy's agreement with the Alliance, the AGS is being developed by United Defense as a large-caliber gun weapon system to provide high-

volume sustainable fires in support of amphibious operations or the joint land operations. After careful consideration of using fixed vertical gun barrels, technical merit and industry discussions drove industry design teams to a mutual decision to develop two trainable, single-barrel 155mm guns, integrated gun and fire control systems, and an automated magazine storing as many as 1,500 rounds. Built by United Defense, each gun will be capable of firing up to 12 rounds per minute. The AGS includes development of a 155mm version of the ERGM as well as other munitions.

Naval Surface Fire Support

The mission of the Naval Surface Fire Support program office is to design, build, and field responsive, lethal, and affordable NSFS combat systems that will meet land warrior requirements. The requirement for improved NSFS has become increasingly important since the end of the Cold War and the subsequent decommissioning of the battleships. The capabilities planned for this program are critical to a ground force's ability to destroy targets of interest and to maneuver without having to carry as much artillery. Key developmental systems managed by the NSFS program include:

- MK 45 Mod 4 5" Gun Mount
- 5" Extended Range Guided Munition
- Land Attack Standard Missile
- Naval Fires Control System
- Land Attack Missile Fire Control

Advanced Land Attack Missile

The ALAM program will deploy a longer range, higher lethality, and more responsive missile than the Land Attack Standard Missile (LASM). The requirement for this all-weather missile is to engage fixed and time-critical re-locatable targets potentially as far as 300 nm from the ship. The Navy plans to integrate it into the DD 21 System

with potential to backfit on submarines and Aegis ships.

Integrated Power System

IPS is a collection of technologies that integrate shipboard electric power systems so that the total power generated by common prime movers can be used interchangeably for both propulsion and other shipboard power requirements, including weaponry and load servicing. While both teams have committed to the incorporation of integrated power/electric drive systems for DD 21, a number of different generation, distribution, and propulsion motor concepts are under study.

Integrated electric power brings particularly compelling advantages to surface warships, including higher power density, more precise control, and flexibility in the internal arrangements of machinery spaces, shafting, and prime mover components. This leads to lower total ownership costs through 15-19% fuel savings, reduced maintenance and manning, as well as eliminating auxiliary systems now using steam, hydraulics, and compressed air. Also, the ability to divert a larger percentage of total onboard power for non-propulsion needs may lead employment of futuristic weapon system concepts. (Truver 1999)

A major technology challenge here is devising power control and isolation techniques that will permit the propulsion system and other "high end" users to operate from the same power buses as the much more sensitive computer and sensor electronics. The Royal Navy's experimental trimaran, *R.V. Triton*, will be used as a test bed for several of these innovations.

Some elements of the associated Office of Naval Research (ONR) science and technology program (described below) also

are addressing these and other advanced IPS concepts. The ultimate goal is an "Electrically Reconfigurable Ship" that would minimize upkeep and operator manning, while providing for automatic re-routing of power and re-allocation of loads in emergency situations.

Affordability Through Commonality

The ATC program oversees collaborative efforts between Navy and industry to identify applications for physical open systems architecture (OSA) and attendant common ship/equipment that would permit zones/systems to be reconfigured with new/upgraded systems without major reconstruction. Similar to the open architecture for the Total Ship Computing Environment, common or OSA interfaces for system "functional elements" will improve the integration of COTS technology. By using this architectural approach, combined with modular packaging of equipment, benefits should accrue in procurement, production, and technology insertion resulting in lower TOC.

Use of OSA interfaces will: facilitate competitive procurements without hindering hull design and construction schedules; minimize baseline redesign during production; support advanced build strategies to maximize the number of parallel assembly lanes, thereby shortening construction time; and allow off-ship testing. In addition, ease of access and installation will permit "just in time" technology to be put into the ship.

Some examples of OSA implementation include an Open "SMART" C4ISR space concept that is easily reconfigured in response to mission or technology changes without impacting the structural, HVAC, and data distribution systems. Another is an Open Chilled Water module that can accommodate multiple current and

projected future commercial systems and technologies. These examples of open architectures will be key to mission and technology adaptability of future ships, including DD 21.

PROGRAM RISKS AND RISK-REDUCTION STRATEGIES

As a path-breaking endeavor, the DD 21 program has had to maintain heightened concern for typical risks inherent in a pioneering effort and to manage or reduce associated programmatic and technical risks accordingly.

The Control of Programmatic Risk

In the programmatic area, DD 21's stringent cost goals can only be met if several key management and technical innovations can be brought to fruition simultaneously. For example, unless the minimal manning goals can be met – essentially a *technical* and *operational* challenge – total ownership costs for the class will increase. Containing the life cycle cost of the class is expected to be a key benefit of maintaining design/development competition in the program until the Phase II downselect. By requiring the design teams to treat cost as one of the key independent variables, the Navy's procurement process invokes the best principles of Acquisition Reform and the Revolution in Business Affairs to minimize *a priori* constraints on design choices, tradeoffs, the selection of contractor-furnished equipment (CFE), and a corresponding logistics approach.

As described above, the successful FSC will bear a larger overall responsibility for containing total ownership cost than ever before, and its profitability will depend crucially on not only the original system design, but on its long-term economic viability and its ability to manage it

efficiently. Thus, the structure of the program itself creates incentives for the contractor teams to minimize programmatic risk directly, and ties long-term profit to their success in doing so. Although several other major defense programs have adopted some elements of the FSC approach – the *San Antonio* (LPD-17)-class amphibious assault ship, the Marine Corps V-22 tilt-rotor aircraft, the Army's *Apache* helicopter, and the Air Force C-17 and C-130J – DD 21's use of the concept is more all-encompassing than previous attempts. Dr. Jacques Gansler, Undersecretary of Defense for Acquisition, Technology, and Logistics, has called the DD 21 program "a real-world laboratory" for proving Navy Acquisition Reform principles.

FSC will have significant ramifications for the future of the surface fleet, with major changes rippling into operations, the shore establishment, logistics, and training. With so much hinging on FSC's success, the program office has instituted an Integrated Product Team to monitor the evolution of the process, with representatives from Navy and industry. Under particular scrutiny are the FSC business cases of both design teams. Also, fleet liaison officers with the Type Commanders in Norfolk and San Diego will ensure continuing waterfront input and concurrence.

Reducing Technical Risk

To maintain "continuity of development" between acquisition phases, DD 21 uses a secure Internet-based integrated data environment with industry to provide a centralized body of knowledge and efficient means of communication among physically-separated design teams, divided – for competitive reasons – by appropriate firewalls. This shared data environment will support the evolution of each industry concept into a three-dimensional virtual prototype to facilitate both simulation-based and detailed design acquisition. The virtual

prototypes will be expanded by industry to link with their physics-based modeling and warfare and logistics analyses to simulate a comprehensive technical and operational definition of DD 21. These Smart Product Models will be carried by both teams up through the downselect, ready for use in the follow-on acquisition as the design transitions to hardware. This evolutionary approach will provide substantial cost and performance benefits, as well as reduce the risk of technical surprises later on.

Previously, during DD 21's concept exploration, the Navy developed a common set of Design Reference Missions (DRM) and provided them to each industry team. The DRMs offer both a general operational context and more detailed warfare scenarios/environments as a basis for the industry teams to demonstrate the performance of their respective DD 21 System concepts.

Challenges of Optimal Manning

Achieving the manning goals set for DD 21 will require a careful tradeoff between the cost of the crew and the cost and complexity of the automation that reduces its numbers. Seeking a reduction of two-thirds or more from the manning of the DDG-51 class would be challenge enough, but with DD 21 a larger and more capable ship, the bar is raised even higher. There are few technical barriers to using automation to reduce the number of watchstanders needed for normal steaming. Many recent innovations practiced in the cargo and cruise ship industries can be readily adapted, particularly with the potential for manpower reductions offered by electric drive. In many situations, automation will materially reduce the likelihood of human error and thus minimize the number of personnel now spent monitoring equipment and checking on each other.

Fighting the ship within a fast-moving littoral scenario, however, will require a

quantum increase in DD 21's ability to fuse incoming data in multiple formats, present information in a meaningful way, and accelerate responsive command decisions. For this reason, the DD 21 program office has supported the study of a number of Integrated Command Environment (ICE) concepts intended to offer a more advanced, functionally integrated command space than today's Combat Information Center (CIC). These concepts are focused on providing the combat team with *knowledge* of the operational environment by ensuring instant access to information from a variety of onboard and off-board sensors. Within the ICE, the combat team will be presented tactical information (i.e., pre-processed data) in a manner that both optimizes the number of team members required to perform a particular mission and minimizes the time to react to warfare developments.

Several candidate configurations have been examined, including spatial arrangements characterized variously as "arenas," "cockpits," "boardrooms," and "huddles." More important than the physical arrangements, however, is the need to devise computer-aided situation displays that also provide recommended courses of action and their probabilities of success. Tactical scenarios in the littoral have become so complex, and require the assimilation of so much information to comprehend them, that the TSCE will need to assume much of the preliminary task of winnowing, ranking, and interpreting this incoming information. By using rule sets, embedded doctrine, and multi-mode reasoning, the decision system will simplify the essentials of evolving situations so that the commander and his small staff are presented immediately with optimized alternatives and the means for executing them automatically.

Although Total Ship Computing will ease the decision load on the operators, the smaller crew must also be able to control

damage if the ship finds itself *in extremis*. (Fitzgerald 1999, Lyons 1998, Vining 1999) While the automation efforts of both design teams to eliminate as many traditional, labor-intensive functions as possible will "free up" a significant percentage of the crew for damage control, the greatest benefits are expected to accrue from a variety of technical innovations.

For example, situational awareness of both the external tactical scene and the ship's internal battle condition will enable "pre-emptive damage control" by automatically maneuvering the ship or reconfiguring onboard systems to minimize the damage from potential explosions. Pervasive remote sensing and interior communication systems would then provide early warning and automated localization of fire and flooding, thus reducing the size of damage control teams needed to respond. Further, architectural improvements, shock-resistant hull structures, and advanced fire-fighting agents will all play a part in increasing inherent survivability, especially since they are being incorporated into the "clean sheet of paper" design from the keel up.

Controlling New Technology

In introducing new and advanced technologies into the DD 21 System concepts, the Blue and Gold design teams are seeking to maximize warfighting capability while simultaneously minimizing ownership cost. They must ensure that these new innovations can be delivered within cost and schedule limits – and indeed that warfighting requirements can be met reliably.

Fortunately, there are several checks and balances in place to minimize these risks. In the first instance, the unprecedented freedom granted the designers to adopt a minimally constrained approach will be accompanied by a high degree of contractual and fiscal responsibility for meeting the requirements – not only at

delivery, but over the life cycle of the ship. One outcome of the FSC approach is the ultimate shipbuilder's vested interest in not over-reaching the technology, with so much of his long-term profitability hinging on its reliability and success.

ONR Participation

Meanwhile, in accordance with a Memorandum of Agreement signed in March 1998, the Office of Naval Research (ONR) is pursuing a focused science and technology program addressing a number of other DD 21-relevant topics. ONR has devoted about ten percent of its budget – largely on the “mature,” advanced development end of the spectrum – to risk-reduction efforts in areas such as human factors engineering, fuel cell power systems, power electronics, advanced composite materials, a hydrodynamically advanced double hull, and innovative degaussing approaches. All of these will add to the technology menu from which the Blue and Gold teams can select mature design features for the ship.

One of the most important of these efforts, involving industry, academia, and the Navy technical community, addresses new methodologies for the integrated design of hull and propulsion systems in advanced ship types. A separate, wide-ranging Manning and Affordability initiative explores innovations in a human-centered design environment to enhance the presentation quality and comprehension of complex information for shipboard monitoring and control.

Similarly, a Multimodal Watchstation is being prototyped to investigate common automation techniques for shipboard command and display consoles and to determine the degree to which the assimilation of operational and ship's status information can be made more efficient by new integration and display techniques. In light of concerns about the effects on

damage control of minimal manning, ONR is also funding this pioneering work. Recognizing the sequential requirement to *sense and assess* shipboard damage, and then to *respond* quickly and appropriately, Navy researchers are addressing both stages. The Reduced Ships-crew by Virtual Presence (RSVP) project seeks to create a pervasive network of interior sensors that will detect and assess fire, smoke, flooding and subsystem health remotely for superior situation awareness. Micro-electro-mechanical systems (MEMS) are prime candidates for creating an affordable sensor-rich environment.

Automated fire and smoke suppression systems will provide the means for quick, centrally directed response with immediate feedback. A former Landing Ship Dock, the ex-USS *Shadwell* (LSD-15) serves as an experimental test bed for these systems, and already, the water-mist approach to suppressing fires in remote compartments has shown substantial promise. In synthesizing a “system of systems” for damage control, the overall strategy has been to enhance and improve existing, labor-intensive manual techniques and then to progress toward automation of these on a step-by-step trajectory.

Additionally, a new series of live-fire tests on the ex-USS *Richmond K. Turner* (CG-20) and the ex-USS *Dale* (CG-19), conducted by the DD 21 program office, have been used to gather new and authoritative data on structural damage effects from both underwater explosions and missile hits. All of this information and lessons learned have been made available to the design teams for their use in assessing alternative hull forms.

STATUS AND FUTURE PLANS

On 12 June 1998, the Navy started the formal contracting process by awarding an initial Phase I "agreement" to the Shipbuilder Alliance to begin planning an acquisition strategy for government approval. Funding was then provided to support the competing Blue and Gold teams in a 14-month comprehensive Phase I effort on Program Definition and Concept Development, which was completed at the end of fiscal year 1999. A firm-fixed-price agreement modification for the next phase was subsequently awarded to the Alliance in November 1999.

Now in Agreement Phase II, Initial System Design, the two teams are developing competitive system designs and accompanying Smart Product Models to demonstrate system performance in virtual media. At the end of Phase II, anticipated in April 2001, the Navy will downselect to a single Full Service Contractor, who will lead the completion of the design, begin construction, and provide life cycle support for the DD 21 class. Contract award for the first ship is expected in FY 2005, with delivery anticipated in 2010.

CONCLUSION

As the Navy moves into the uncertainties of the 21st century, the need for a new generation of surface combatants becomes increasingly insistent. In responding to this requirement against the background of resource limitations, a tenuous industrial base, and the need for new technology insertion, DD 21 has adopted a radically new acquisition approach that significantly alters traditional roles by inviting competitive industry teams to make cost-conscious decisions within the context of the ship's total life-cycle process. In relinquishing a greater share of design and life-cycle responsibility to the private sector, the Navy seeks to capitalize on the

proven innovation and effectiveness of U.S. industry in propelling the economy to new levels of prosperity. While risks and uncertainties abound, the prospects are promising. And given the urgency of the need and the scarcity of our resources, there may be no other real alternative than far-reaching acquisition reform as demonstrated by DD 21.

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